Message Dissemination in Social Networks for Support of Information Operations Planning

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ABSTRACT

Message dissemination is often an important part of many provincial reconstruction efforts. This dissemination is affected by many factors that may only be partly known, such as the impact of the information, the social network structure, socio-cultural factors that affect the information dissemination, and at what point the information looses its news value in verbal communication. Understanding and managing how all factors that affect the message dissemination may interact pose a complex problem even for experienced Psychological Operations (PsyOps) officers. This paper therefore proposes that modelling and simulation (MoS) techniques based on epidemiological modelling can be used to cope with the complexity when planning information operations. Particularly, regarding what portion of the target population is reached by a message and within what timeframe. The paper describes how the epidemiological framework can be applied to a scenario that is used for combined staff exercises within the Swedish Armed Forces. The main focus is how cross-cultural dimensions, such as Hofstede's five dimensions, and other socio-cultural factors can be used to derive the social network structure and contact rate for message dissemination. The results illustrate the assumed effects of socio-cultural factors on message dissemination and the need for a coherent theoretical framework that provides some understanding of how the social network and contact rates are shaped by socio-cultural factors.

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1.0 INTRODUCTION

An important aspect of any provincial reconstruction effort is how to properly disseminate relevant information to the target population within the area of responsibility. Such dissemination may be performed by many means, such as mass media in the form of TV and radio, information technology, such as telephones, mobile phones, and the Internet, newspapers, leaflets, and word of mouth. Further, some information is only accepted when several information channels are combined. For example, by combining mass media and word of mouth so that the mass media raises the awareness of an issue and that the word of mouth from a trusted source indeed supports the issue.

Many information channels are also available even in less developed countries that are in need of provincial reconstruction. Typically, however, word of mouth becomes relatively more important since other channels often are less available, particularly in rural areas. The problem with word of mouth is that the dissemination relays on many factors that are only partly known, such as the impact of the information, the social network structure, socio-cultural factors that affect the information dissemination, and at what point the information looses its news value in verbal communication. Although the actual nature of these factors may never be completely known, there is a steadily increasing amounts of research that allow a general reasoning about message dissemination in various contexts. For example, how individuals are susceptible to information that is positively coherent with prior beliefs and goals [1], and how information that is relevant to the preservation of a group's interest is more likely to be communicated within the group rather than across groups [2]. Other examples are how the local dependencies between actors foster the typical quam social networks found in Afghanistan [3], and how group membership, such as ethnicity, is a primary basis for social interaction [4][5].

Typically, understanding and managing how all factors that affect the message dissemination may interact pose a complex problem even for experienced Psychological Operations (PsyOps) officers. A pertinent issue is therefore to what extent modelling and simulation (MoS) techniques can be used to cope with the complexity when planning information operations. Particularly, regarding what portion of the target population is reached by a message and within what timeframe [6]. This prompted TNO Defence & Security and the Swedish Defence Research Agency (FOI) to cooperatively develop a generic message propagation simulator with the working title SHOUT (Simulating How Utterances Transmit). SHOUT is developed as a part of the European Defence Agency (EDA) project Socio-Cultural Modelling (SOCUMOD) [7].

The purpose of SHOUT is to enhance the PsyOps officers' sense-making for how socio-cultural factors affect the message dissemination when planning operations with only typical computer hardware available, such as a standard laptop. The current assumption in SHOUT is that these requirements for simplicity and computational resources can be met by approximating the message dissemination with epidemiological principles for how diseases spread in a population (e.g. [8]). In epidemiological modelling, individuals typically transition between disease states, such as susceptible, exposed, infectious, and recovered depending on disease specific time constants and a sufficiently detailed representation of the contact rate between individuals. The idea in SHOUT is that such state transitions, time constants, and contact frequencies can also be used for modelling of how socio-cultural factors affect the message dissemination. Although epidemiological principles are only a crude approximation of message dissemination, it can provide a general understanding of how the combination of known factors may impact the dissemination.

The purpose of this paper is to describe the latest developments of SHOUT, and how SHOUT has been applied to message dissemination in a representative scenario that is used for concept development and experimentation (CD&E) within the Swedish Armed Forces. The main purpose is to exemplify how to reason regarding the effects of socio-cultural effects on message dissemination and how these effects can be represented in SHOUT. The goal is not necessarily to have the most accurate model. The rest of the

paper begins with a brief review of socio-cultural factors that affect message dissemination, followed by the latest SHOUT development, some examples of message dissemination using SHOUT, and recommendations for future developments.

2.0 SOCIO-CULTURAL EFFECTS ON MESSAGE DISSEMINATION

The effects of socio-cultural factors on message dissemination are broadly addressed with a combination of cross-cultural psychology, cross-cultural communication, and social network theory. Cross-cultural psychology focuses on how cultures affect behaviours and mental processes and thereby the communication patterns within different cultures. Cross-cultural communication, on the other hand, focuses on cultural factors that affect the communication between individuals from different cultures. Finally, social network theory focuses on the characteristics and generation of typical social networks, as well as how the networks affect information dissemination. The following is a brief review of each of these areas as they pertain to message dissemination.

2.1 Cross-Cultural Psychology

Many useful frameworks have been developed for studies of cross-cultural psychology, such as the Basic Human Values [9] and the world value survey [10]. However, although criticized, Hofstede's cultural dimensions is still one of the most adopted frameworks. Hofstede [11][12] describe how many cross-cultural phenomena can be characterized along five dimensions:

1) Individualism vs. Collectivism characterizes whether members define themselves as apart or part of their group membership. Members of individualist culture are expected to promote their individual personalities, while members of collectivistic cultures mostly act as members of a long-term group.
2) Power Distance characterizes how resources and information is controlled. In high power distance cultures, only a few people control the resources and information and they are expected to take the initiative, while low power distance cultures have a more equal distribution of resources and information.
3) Masculinity vs. Femininity characterize whether cultures emphasize "male" value, such as competitiveness, or "female" values, such as relationships. These values are often related to gender egalitarianism.
4) Uncertainty Avoidance characterize to what extent cultures cope with their anxiety towards the unknown by using rules and formal structures to minimize the uncertainty.
5) Long vs. Short-Term Orientation characterize whether cultures emphasize the importance of future developments or the past and present.

Further, a culture's values along these dimensions have a direct impact on the behaviour and practises within the culture [13]. For example, Khalil and Seleim [14] tested nine hypotheses on the impact of national culture practices (as measured by [15]) on information dissemination capacity across 61 countries. They found a high negative effect of in-group collectivism and a moderate negative effect of power distance on information dissemination. The negative effect of power distance is due to that in high power distance cultures few people have access to resources and initiatives are expected to come from the top management. Further, there was a moderately positive effect of uncertainty avoidance and future orientation on information dissemination. Surprisingly, there was no effect of gender egalitarianism although previous studies indicate that gender egalitarianism would be positively correlated with information dissemination. These results are also partially supported by Bagchi et al. [16] who found less adoption of information technologies in high power distance, uncertainty avoidant, and masculine countries.

2.2 Cross-Cultural Communication

Unfortunately, the effects of cultural values along Hofstede's dimensions are not as straight forward for cross-cultural communication. For example, Hofstede [12] describe how integration across dividing lines is more difficult in collectivist and uncertainty avoiding countries than in individualistic countries. Both these negative effects are contrary to the positive effects for information dissemination within the same culture. Since the effects depend on the culture receiving the information, the cultural value for this culture is used. There is also a negative effect of masculinity since inequalities limits the communication in general. A reasonable assumption is that the information dissemination is limited by the part with most masculinity. Further, there are asymmetric effects of power distance since high power distance cultures have problems functioning in low power distance cultures, whereas low power distance cultures function well even in high power distance cultures. This means that there is only a negative effect of power distance if the sending part has a higher power distance than the receiving part. Finally, differences in long-term orientation mean that the cultures talk about different topics. This effect may therefore be characterized by the relative difference between the two cultures values in long-term orientation. Regarding the relative importance of the cross-cultural dimensions, it is probably similar to the information dissemination within the same culture. The only exception is uncertainty avoidance since differences in uncertainty avoidance are more difficult to manage than differences in power distance.

In addition to the effects of differences in cultural values, cross-cultural communication is also affected by many other socio-cultural factors. For example, previous conflicts between the two groups will probably have a strong negative effect on the cross-cultural communication. Similarities in language, religion, and political participation as well as economic and other incentives to cooperate, on the other hand, should have strong positive effects on the communication. Moderate positive effects may also be obtained from similarities in habits, attire, social economic status, and family size. This type of differences may also be readily available for assessment by PsyOps-officers.

2.3 Social Network Theory

Generally, group membership is the primary basis for social interaction, where the probability of two people knowing each other decreases with decreasing similarities of the groups to which they belong [4]. The ingroup versus outgroup distinction explains why individuals within the same groups have stronger ties, as well as many reports about boundaries between ethnic groups in social networks (see [5]). While the strong ties carry much of the communication within the groups, the communication between groups is actually performed through intermediate or weak ties [17][18][19][20]. Such ties are therefore very important for the message dissemination through a region or country.

In addition to the effects on contact rates, Hofstede's cultural dimensions also characterize cultural differences in the social networks for who communicate with whom. For example, one explanation of the higher density of Israeli compared to US networks is the Israeli's higher proportion of kin ties, longer lasting relationships, and greater group cohesion [21]. These results illustrate how collectivistic cultures place a higher importance on ties to the family, relatives and neighbourhood, relative to ties that are related to the individual performance, such as profession, social associations, and friends [12]. Another important cultural difference is that centralisation is typical for high power distance countries. This means that the within group dissemination to a large extent depends on central persons "opinion leaders" who have strong ties with the other group members [22]. The other group members then mainly turn to this central person for information. Such hubs are therefore important for the message dissemination. Finally, men and women's networks are more dissimilar in high masculinity cultures [14].

Although social network research has a long history it is only recently that mathematical statistics have evolved to a point of studying large social networks that approach the size of regions and provinces. Such studies often characterize networks according to their degree distribution (the distribution of number of

contacts for all the nodes), clustering distribution (the distribution of number of contacts that two nodes have in common), and average path length (the minimum number of steps between two nodes) (e.g. [23]). Many networks, such as the Internet, cortical, and social networks, are characterized by an exponential degree distribution where only a few central nodes have many contacts, but most nodes have only a few contacts. Such networks are referred to as scale-free networks and are similar to the centralisation found in high power distance cultures. However, Watts [24] and Newman et al. [25] describe how it also possible for networks to have a high clustering without decreasing the average path length between nodes. Such networks are often referred to as small-world networks and have many similarities with how peoples' social networks form highly connected clusters.

2.4 Social and Security Factors

Finally, message dissemination both within and between cultures is likely affected by social factors and the general security situation. For example, people typically see no need to disseminate a message further if it is already known by most or if the dissemination is met by unfavourable reactions. It is therefore not necessary for all susceptible people to be informed before the dissemination stops. Essentially, a message looses its news value when a sufficient portion of the population is already informed. Further, the general security situation will also affect the message dissemination since the turmoil, conflicts, and instability of problematic regions typically hinders free communication. Regional stability in SHOUT is therefore characterized according to the states proposed by Dziedzic et al. [26]. State Zero means that the situation is externally stabilized by external military forces in partnership with a sizable international presence. State One means that the stability has improved so that it can largely be managed by local actors and developing indigenous institutions. State Two means that local institutions are able to cope effectively with the remaining drivers of violent conflict and resolve internal disputes peacefully without the need for an international military or civilian administrative presence. An increased stability according to these definitions should facilitate the message dissemination.

3.0 SOCIO-CULTURAL CHARACTERISTICS OF XLAND

The Xland scenario was designed to enable joint combined staff exercise of a European Union Battlegroup size operation at the Swedish Armed Forces facility for concept development and experimentation (CD&E). The scenario covers a UN mandated Chapter VII operation, focusing on a security assistance mission linked to parliament elections in Xland. The scenario setting is based on Northern European geography, in an area called the North Friendly Sea. The scenario is fictitious, but inspired by real world events.

Xland is a small country of about 600.000 citizens and consists of the four municipalities Gävle, Sandviken, Ockelbo, and Hofors. Figure 1 shows the current map of the North Friendly Sea area and figure 2 shows the current map of Xland. About 50% of the population live in Gävle and Sandviken cities and along Highway 80 (RV80) between Gävle and Sandviken. Xland has a long history of strong tensions between the two main ethnic groups Delta and Echo Christians. Table 1 shows the demographic distribution of Echo and Delta Christians in Xland. Most Delta Christians in Ockelbo municipality have their origin from recent immigration from nearby Northland, while the Echo Christians have their origin from Westland. Although Echo and Delta Christians share a similar religious orientation in the form of Christianity, their religious roots from Westland and Northland respectively are very different. Xland was originally a province of Northland, but was lost to Westland following an offensive to establish a corridor to the North Friendly Sea. Eventually, Northland regained most of their territory, although the territory that later became Xland remained under Westland control. In 1909, Xland was declared a sovereign state.

Since the Echo Christian population in Xland was very vulnerable, they early on established laws, practises, and social networks that enable them to control most of the political and economic powers. For

example, only Echo Christians are allowed to own any real estate. The power distribution was for a long time not an issue and accepted by the Delta Christian population. However, this all changed during 1930 depression when a huge influx of Delta Christians from Northland in the western and northern part of Xland changed the ethnic composition in these areas. Social tensions mounted when the Delta Christians were especially affected by the depression. Since than there has been repeated clashes and even massacres. The ongoing political oppression and deteriorating standard of living for Delta Christians during the late 1990s also favoured the emergence of Delta Christian fundamentalist groups. One of these groups was the Klykers who now control the western part of Ockelbo and Sandviken and eastern part of Hofors. The Klykers consistently practise "management by fear" to increase their influence. Therefore, there are no Echo Christians left in the countryside controlled by the Klykers, only in Hofors city. The western part of Hofors is controlled by the Valliens, a maffia-type organisation that is part of the ethnic Valliens population who settled in Hofors in the 17th century.

The fragile security situation in Xland and deteriorating standards of living with 25% HIV/AIDS and ecologically unsustainable logging, forced the authorities to turn to the international community for assistance. The Delta Christians demanded free and fair elections and a date has been set. A formal request for assistance, regarding security and organisation of the election, was forwarded to the UN Secretary General on 27 June 2009.

The documentation of the Xland scenario was used and expanded to identity the socio-cultural characteristics of Xland. The cross-cultural psychology of Delta and Echo Christians is reviewed first, followed by the cross-cultural communication and social network.

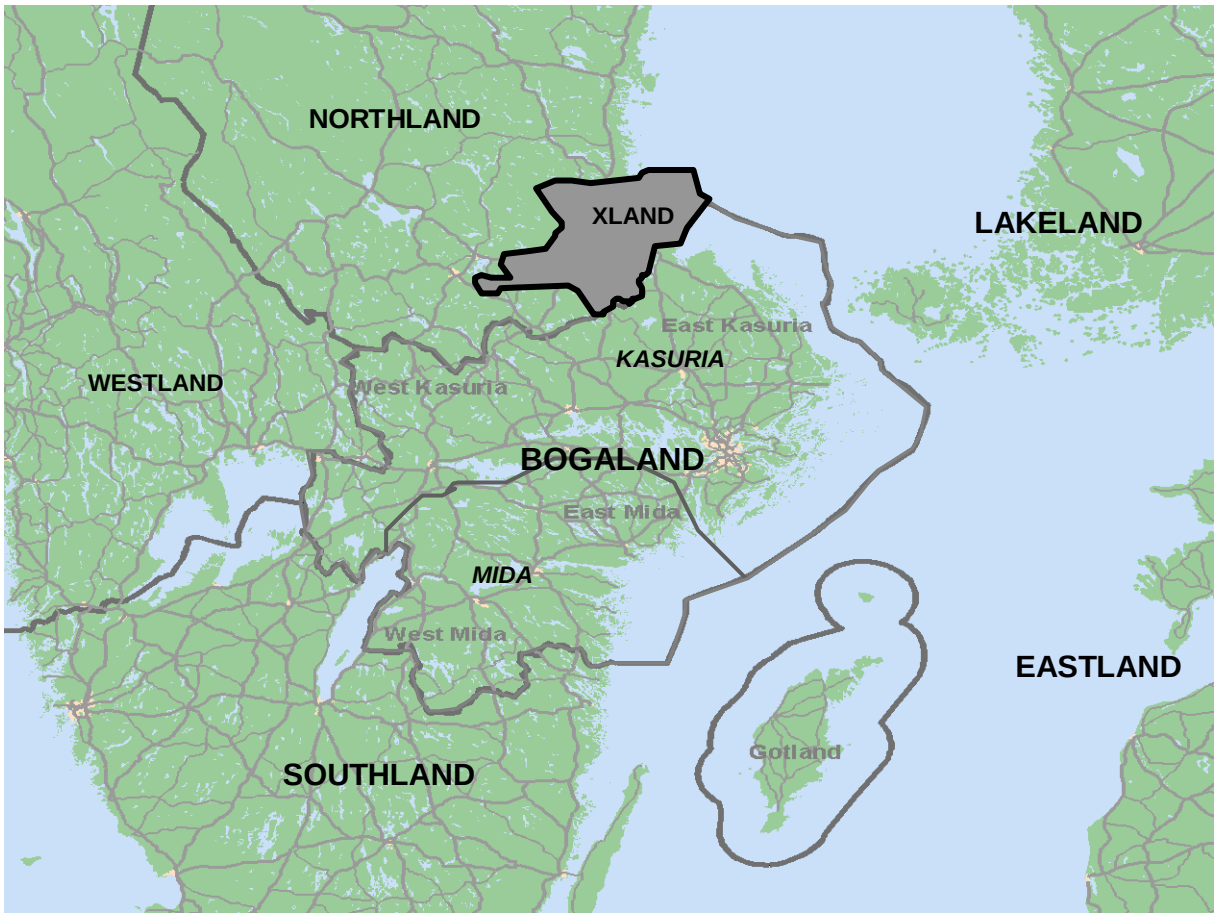

Figure 1: Map of the North Friendly Sea area.

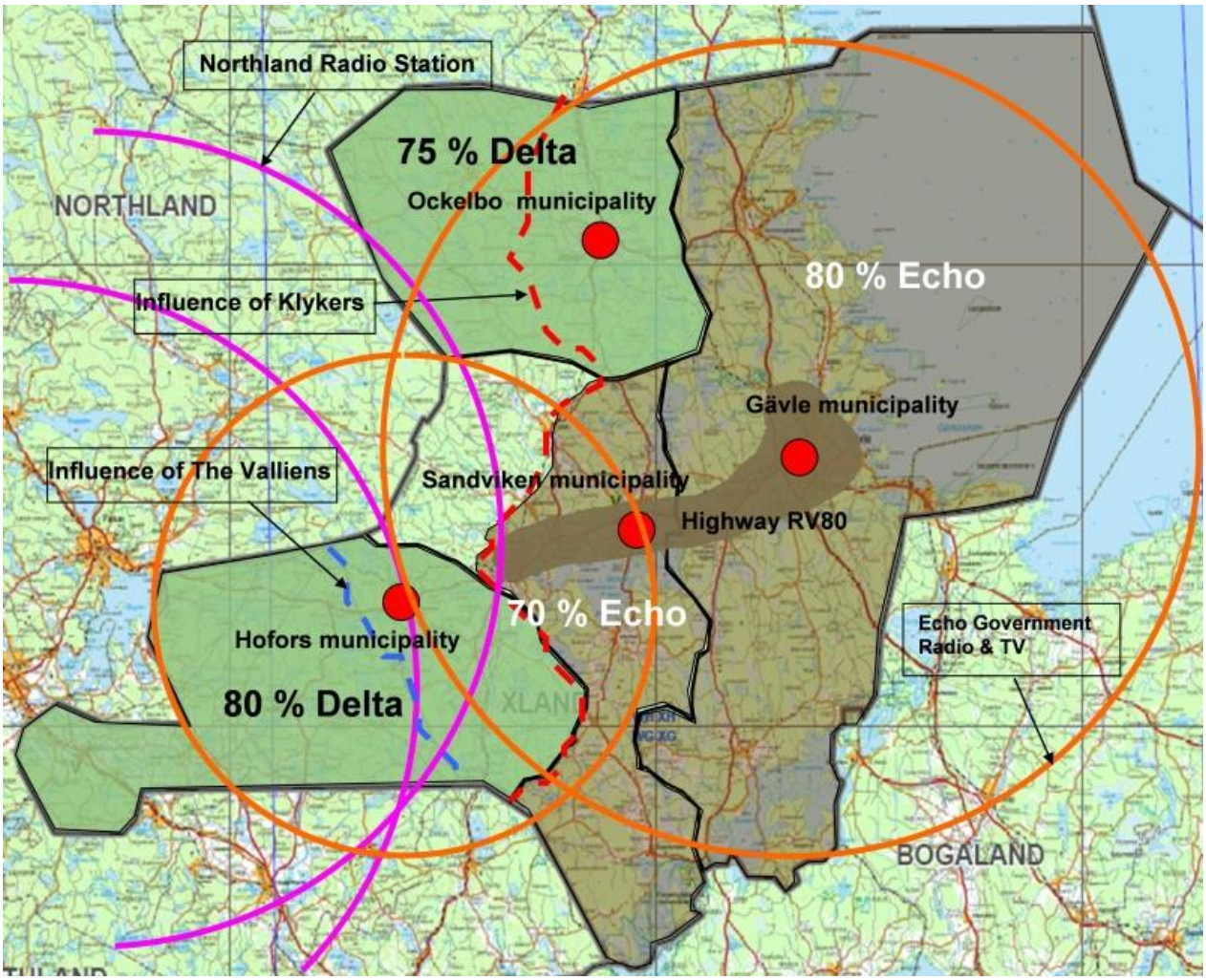

Figure 2: Map of Xland.

Table 1: Demographic distribution in Xland.

	No. Delta Christians			No. Echo Christians			Total
Municipality	Countryside	Urban areas	City	Countryside	Urban areas	City	
Gävle	25000	20000	20000	50000	80000	105000	300000
Sandviken	35000	5000	5000	20000	35000	40000	140000
Hofors	55000		5000	0		15000	75000
Ockelbo	60000		5000	0		20000	85000
Total	175000	25000	35000	70000	115000	180000	600000

3.1 Cross-Cultural Psychology of Xland

Generally, the Delta Christians have traditional values which mean a high power distance and masculinity. The Echo Christians, on the other hand, have a more equal role for men and women which mean a low masculinity. Their more modern values mean that the power distance is low. Typically, Echo Christians

emphasise the importance of social networks for strengthening of their influence which indicate a high collectivism. Delta Christians, on the other hand, have no such traditions although the high power distance influence assures some collectivism. Further, the precarious situation for both Echo and Delta Christians forms the basis for partial radicalization and selective assimilation of information. Both Echo and Delta Christians therefore have moderate uncertainty avoidance. Finally, the Echo Christians have a long tradition of using available means to maintain their dominant position. However, their oppression of the Delta Christians continuously causes tensions. It is therefore reasonable to assume that they have moderate long-term orientation. The Delta Christians, on the other, have a low long-term orientation, partly due the migration patterns as a result of previous conflicts and socio-economic oppression.

Future refinements of the Xland scenario may consider that the Delta Christian communities in the southern part of Gävle municipality are the most isolated from other Delta Christian communities. These Delta Christians might feel vulnerable, which possibly make them more receptive for Delta Christian as well as other radical political manipulation. Similarly, Echo Christians that are isolated or live near Delta Christian areas may feel vulnerable and be subject to radicalization.

3.2 Cross-Cultural Communication in Xland

Regarding the potential communication between Delta and Echo Christians, there are cross-cultural factors that facilitate, as well as hinder communication. A strong positive factor is that the general language in Xland is Xlandian. Although each municipality in Xland has its own dialect, the difference is not greater than that the dialects are understood in all parts of Xland. Therefore, Echo and Delta Christians have a high language similarity. Further, there is no indication that the different religious roots of Echo and Delta Christians have significantly affected their communication habits in different ways. Their habits are therefore highly similar. Likewise, the cultural expression through attires is highly similar for Echo and Delta Christians. Although Echo Christians generally are wealthier than the Delta Christians they do not appear to express their ethnicity or socio-economic status with specific attires. Finally, both Echo and Delta Christians have strong political parties that represent their position. The interest in a political solution is therefore high on both sides. Consequently, there is a high motivation for political discussions between Echo and Delta Christians.

The factors with only a moderate or weak positive effect on the communication is the two different religious orientations of Christianity, the difference in family sizes, differences in socio-economic status. Although Echo and Delta Christians share a similar religious orientation in the form of Christianity, their religious roots from Westland and Northland respectively are very different. This means that there is only a moderate religious compatibility between Echo and Delta Christians. Further, due to a high nativity, a typical Delta Christian household has 6-8 children, two parents, and at most two grandparents. A typical Delta Christian household therefore consists of about 10-12 residents. A typical Echo Christian household, on the other hand, has 1-3 children, and two parents. A typical Delta Christian household therefore consists of about 3-5 residents. Therefore, there is only a moderate similarity in family size. Finally, Echo Christians have a long fundamentalist tradition of oppression towards the Delta Christians and use laws, social networks, bribery and nepotism to maintain their domination of political and private positions. The result is considerable socio-economical inequality which has motivated much of the Delta Christian resistance and demand for free elections and equal rights. Therefore, the socio-economic equality is low between Delta and Echo Christians.

A strong negative effect on any communication between the two groups is the fact that the Echo Christian oppression of Delta Christians has resulted in several conflicts in the form of demonstrations, riots, massacres, and skirmishes with irregular forces. Therefore, there is a high conflict between the two main ethnic groups.

3.3 Social Stability in Xland

The main irregular groups that restrict the freedom of movement and speech are the Klykers, Valliens, and Gastrikans. The Gastrikans are sponsored by Westland enterprises and have their stronghold around Gävle. Although they will attempt to disrupt the elections they are to few and do not have enough support by the government to perform any major actions. It is in the Echo Christian interest that the election is perceived as sufficiently fair so that result can legitimize the Echo Christian dominance. The main threat may instead the increasing support, even among the Echo Christians, for the Environmentalist Party which focus on sustainable socio-economic development rather than only focusing on ethnic rights. Further, geopolitical vulnerabilities of Delta Christians in Gävle municipality and Echo Christians in Sandviken municipality may create the basis for radicalization. Still the government security forces with support from the international community are expected to provide a sufficiently fair election within their area of control. This means that the social stability is high in Gävle municipality, along RV80, and the eastern part of Sandviken and Ockelbo municipalities which together compromise about 81% of the population in Xland.

The main security problems are in the west of Xland that is controlled by the irregulars Klykers and Valliens. The Klykers are Delta Christian fundamentalist who are known to systematically practice "management by fear" as a means to increase their influence. Delta Christians in general, extremists like the Klykers included, should have no incentive to hinder or severely obstruct the election, as they have much to gain from an outcome that could give Delta Christians substantial influence. However, Groups among the Delta Christians may be tempted to use excessive means to affect the outcome. From a Delta Christian point of view it is important to achieve a very high voter turnout among Delta Christians, and if possible lower the voter turnout among Echo Christians. The situation is particularly precarious for the Echo Christian population in Hofors who are under Klykers control. Generally, this means that social stability is moderate in the western part of Ockelbo, Sandviken, and the eastern part of Hofors municipalities. About 13% of the population in Xland is under Klykers control.

There are also problems in the western part of Hofors that is controlled by the Valliens. The Valliens is a mafia-type organisation that is part of the ethnic Valliens population who settled in Hofors in the 17th century. Their main source of income is mining using a recent influx of Delta Christian refugees from Bogaland as slaves in the mine. Other source of income are taxing of local business, thefts of private and governmental resources, plundering of aid transports, smuggling, arms trade, trafficking, and contract killings. However, they also operate legal businesses, such as bars, hotels, and transport companies. Although the Valliens have not stated any interest in the election, they likely want to maintain the status quo since their operation is so profitable. This may explained why they recently performed a contract killing of the Delta Liberation Front party leader. In 2003 they also evicted all international organisation and non-government organisations. Overall, however, the Valliens maintain a moderate social stability in the western part of Hofors which compromise about 6% of the population in Xland.

3.4 Demographics in Xland

Only people that are older than twelve years of age are expected to contribute to the message dissemination. Since the Delta Christians have a strong population growth rate due to their high nativity, their growth rate is comparable to many African countries. The top ten countries in the The World Factbook (CIA) has more than 3% annual growth rate. Assuming a similar growth rate for Delta Christians means that only about 60% of the population is over twelve years of age. The nativity of the Echo Christians, on the other hand, is more similar to many western countries with an annual growth rate of about 0.3%. Assuming a similar growth rate for the Echo Christians means that about 85% of the population is over twelve years of age.

3.5 Information Channels in Xland

Figure 2 shows that the mass media of radio and TV only partially cover Xland. TV coverage is particularly limited since the transmitter in Hofors is only a radio transmitter. All mass media in Xland is controlled by the Echo Christian government. There are also some satellite-TV receivers, but they are only available for the wealthiest 5% of the Delta Christian households. Cell phones, on the other hand, are widely available where 50% of the adult Delta Christians in cities and 90% of the adult Echo Christian population has a cell phone. Additionally, 90% of the villages have at least one cell phone. Further, there is also some Internet access available for 1% of the Delta Christians and 20% of the Echo Christians in the cities. Generally, only wealthy households have access to information technologies, which makes it possible to stay in closer contact with each other as well as relatives. Finally, literacy is very unequal in Xland since only the Echo Christians are typically wealthy enough to send their children to school for education. The Echo Christian literacy is therefore similar to many developed countries with around 99%. The poverty, oppression, and mobility of Delta Christians, on the other hand, mean that they are not so fortunate and their literacy is only 50%.

Currently, word of mouth is the only information channel that is implemented in SHOUT. The other information channels may be included in future versions. Please see Vliet et al. [6] for a discussion about channel characteristics.

4.0 EPIDEMIOLOGICAL MODELLING OF MESSAGE DISSEMINATION

Since message dissemination is partly similar to how infections diseases spread in a population, one approach for modelling message dissemination is the epidemiological modelling and simulation framework (e.g. [8]). In epidemiological modelling, the spread of diseases is often represented as the disease state of individuals, such as susceptible, exposed, infectious, and recovered, as well as possible transition and time constants for transition between the states. The state and transition framework is then applied to a resolution level of the population that is appropriate for application. This may be the whole population, subpopulations, communities, or individuals. Although there are many epidemiological models available, most applications have their own specific requirements. The models are therefore typically customized for the specific needs. Since SHOUT is intended as an explorative tool for PsyOps-officers to investigate socio-cultural effects on message dissemination, both overall and individual population models are inappropriate. Representing the whole Xland population within a few message states does simply not provide enough resolution, and representing each individual is too complex for the computer resources that PsyOps-officers typically have available.

The best option for SHOUT was instead to represent the social network as an agglomeration of communities that reflect the structure and tie strength of the social network. This can be viewed a clustering of families and contacts with strong ties into communities and aggregation of the ties between families. Essentially, the model is a metapopulation SEIR-model [8]. The SEIR means that the individuals in a community are either Susceptible to a message, Exposed but not yet disseminating the message, Infections and thereby disseminating the message, or Recovered and no longer disseminating the message. Initially, all communities are susceptible to the message to various degrees. Individuals within one or several communities then become infectious and start disseminating the message within their communities and then through their social network to other communities. The advantage of using a metapopulation model is that the average size of the communities can be adjusted to find a level of complexity that is appropriate for the application. Currently, the average community size in SHOUT is 60 individuals which mean that about 10.000 communities are used to represent the population in Xland.

Equation 1 shows the mathematical representation of the metapopulation SEIR-model in a discrete form, which here means stepwise increments from one time to another. X_{it}, W_{it}, Y_{it}, and Z_{it} are the number of

individuals in community *i* at time *t* that are susceptible, exposed, infectious, and recovered, respectively. λ_{it}, σ_i, and γ_i are the force of dissemination that expose individuals in community *i* at time *t*, and the rate at which an exposed community become infections and recovers, respectively. The rate at which individuals become exposed depends on the community's dissemination rate β_i, the social network matrix or weighted sociomatrix ρ_{ij} for the contact rate between communities, and the proportion of individuals that disseminate the message in the communities. The rate at which communities become infectious can be viewed as the time it takes for a message to disseminate through the community, where α_i is the incubation rate and N_i is the total population in community *i*. γ_i reflects that the individuals who disseminate a message only do so when a sufficient portion υ of the community have not heard the message so far. Individuals recover at rate ψ_i if enough people have not heard the message and immediately if enough people have heard the message. Essentially, the rate of recovery depends on when the message looses its news value.

$$
\begin{aligned}
X_{i(t+1)} &= X_{it} - \lambda_{it} X_{it} \\
W_{i(t+1)} &= W_{it} + \lambda_{it} X_{it} - \sigma_i W_{it} \\
Y_{i(t+1)} &= Y_{it} + \sigma_i W_{it} - \gamma_i Y_{it} \\
Z_{i(t+1)} &= Z_{it} + \gamma_i Y_{it} \qquad \text{(Eq. 1)} \\
\lambda_{it} &= \beta_i \textstyle\sum_j \rho_{ij} Y_{jt} / N_j \\
\sigma_i &= \alpha_i / \sqrt{N_i} \\
\gamma_i &= \left\{ \begin{matrix} \psi_i \,\middle|\, X_{jt}/N_j > \upsilon \\ 1 \,\middle|\, X_{jt}/N_j \le \upsilon \end{matrix} \right\}
\end{aligned}
$$

The main contribution in SHOUT is perhaps that it provides one example how some of the socio-cultural characteristics in section 2 and 3 can be integrated and incorporated as parameters in equation 1. All the parameters in equation 1, in one form or another, describe the transition rate between dissemination states. However, the weighted sociomatrix ρ also reflect the social network structure which depends on the socio-cultural characteristics and spatial relationship. The next section describes how the social network is generated followed by the computation of the transition rate parameters.

4.1 Generation of Xland Social Network

Since the Xland scenario only describes the overall demographics, the spatial relationships were randomized based on the specified demographics. First, the communities' positions and sizes where randomized to provide the specified demographics. The range of community sizes were between 10 and 110 individuals with an average of 60 individuals. Secondly, communities on the countryside within a certain distance where then iteratively moved closer to reflect the effects of resource sharing and that all areas may not be habitable. The maximum distance for moving communities closer on the country side was 2 km. Cities and urban areas do not have this problem to the same degree since there often is some kind of transportation and communication infrastructure available. The random position distribution where therefore sufficient for these areas. Another more accurate approach may be to first generate a network on the family level and then use a clustering algorithm to identity the meta-population communities. However, for the current version of SHOUT it is probably sufficient to directly generate the network at the community level. Figure 3 shows the final positions for the Echo and Delta Christian communities. The result appears to be a representative distribution of small villages.

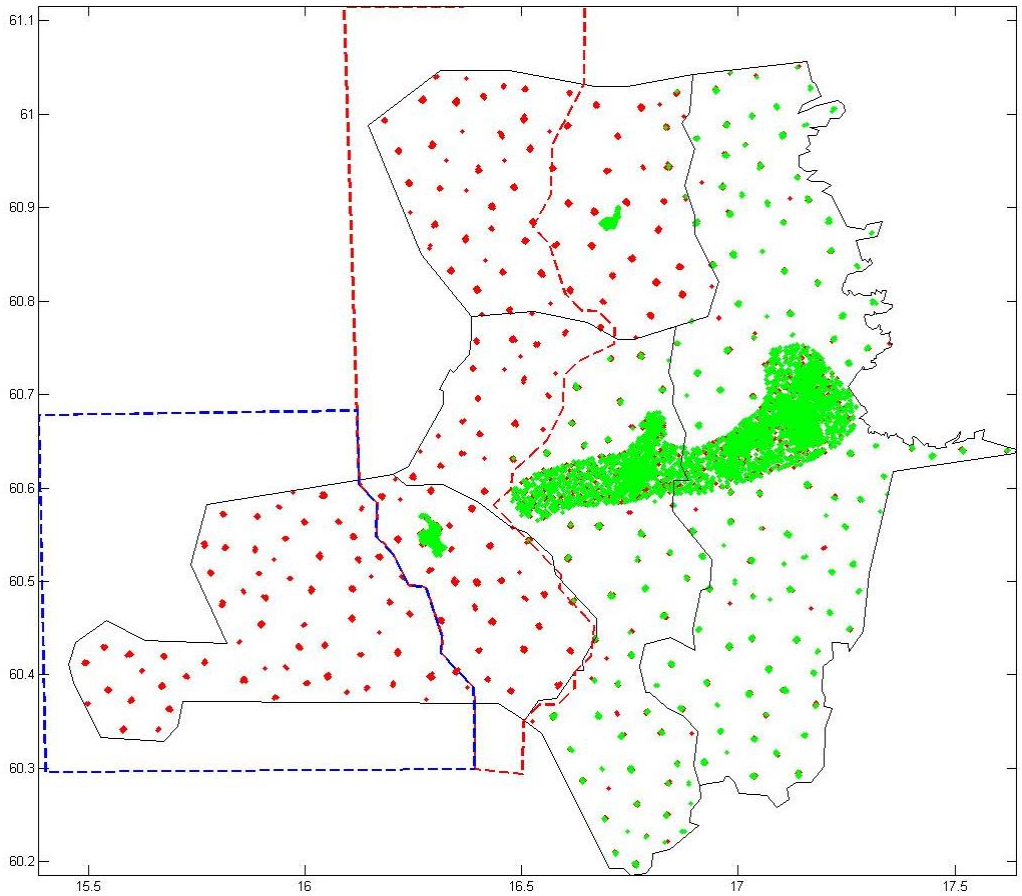

Figure 3: Distribution of communities in Xland where the red dots are Delta Christian communities and the green dots are Echo Christian communities. The Area of Influence for the Klykers (red dotted line) and Valliens (blue dotted line) is also indicated.

Further, the social network structure in Xland between communities of the same ethnicity also depends on ethnicity's power distance where high power distance cultures often have a more centralised network structure. Barabási and Albert [27] describe how such centralised networks can be generated with a preferential attachment where nodes that already have many contacts with other nodes are more likely to attract contacts with new nodes. The resulting network consists of one cluster with a power law degree distribution. Low power distance ethnicities, on the other hand, are more likely to have a localization based network with small-world properties, where nodes form clusters of closely related nodes. However, Toivonen et al. [28] found that many of the methods for generating large networks do not show the high clustering that is typical for social networks. Instead they propose a growth based algorithm where nodes are added to an initial substrate until the network has reached the desired size. Two parameters control the algorithm, the probability for a new node to connect to one or two previous nodes, and the maximum number of neighbours of the previous node that the new node can connect to. However, investigations of the networks showed that these parameters were not enough to generate the characteristic centrality for high power distance cultures. The probability for selecting previous nodes was therefore modified from only a uniform distribution to a parameterized distribution based on preferential attachment [27], and community size distribution since larger communities usually are better connected. The parameter for preferential attachment allows the distribution to vary between uniform, normal preferential attachment and strong preferential attachment. The selection of previous nodes between villages and within cities also included the spatial relationships between communities since the distances between communities may be large enough to affect how contacts are selected [29][30]. The spatial relationships are scaled by a distance

parameter that indicates at which range the spatial relationships become less significant for the selection of previous nodes. The spatial relationships between communities within villages, on the other hand, are typically insignificant.

Figure 4 illustrates the network generation and the parameters that control the contacts between nodes where *a* is the probability for connecting to one or several previous nodes, *b* selects the strength of preferential attachment, *c* is the maximum number of connections to neighbours from a previous node, where k_j is the number of connections for node *j*, *k* is the total number of connections, s_j is the size of community/village *j*, *s* is the size of all communities/villages, d_{ij} is the distance between community/village *i* and *j*, and *rc* is the distance where spatial relationships become insignificant. First, parameter *a* is used to determine whether node *v* should only connect to node *m* or also node *n* and possibly more nodes. Typically, a connection to the first node extends an existing cluster of nodes, where as a connection to a second or more nodes form a bridge between clusters of communities. The node selection for connection depends on the preferential attachment and size distribution for connections within villages, and additionally the spatial distribution for connections between villages and within cities. Finally, parameter *c* determines the maximum possible neighbouring nodes for connection; here neighbours *o* and *l* to *m* were selected. The connection probabilities depend on the size distribution so that larger communities/villages have a higher probability to connect to more neighbours. Parameter *c* therefore influences the formation of clusters. Further, the connection probability between villages and cities depend on city size and the spatial relationships. The selection of communities within villages and cities for connections between villages and between villages and cities depends on preferential attachment, size distribution, and additionally the spatial distribution within the cities. Finally, the interaction between Delta and Echo Christians only occur at workplaces where Delta Christians are a labour force and the Echo Christians are supervisors. The connection probabilities between Delta Christians and a representative number of Echo Christians were based on the size distribution for connections within villages, and additionally the spatial relationships within the cities. Table 2 summarises the types of social network generation and how the parameters were used. The distance *rc* is larger within the cities to account for a better communication and transportation infrastructure within cities.

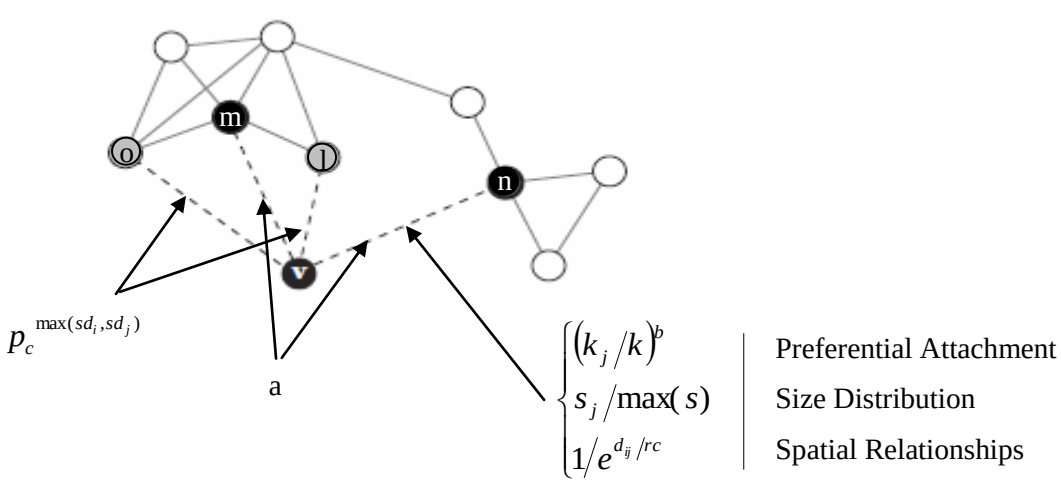

Figure 4: Illustration of network generation and control parameters (see text for explanation).

Table 2: Types of social network generation for Xland and the types of parameters that were used where PD is power distance and PA is preferential attachment.

Network part	Connection to one or two nodes	Selection of nodes			No. of close contacts
	PD	Size	rc	PA	PD
Within villages	X	Communities	NA	Strong PD for communities	Size
Between villages	X	Villages, Communities	5 km	PD for villages, Strong PD for communities	Size
Within cities	X	Communities	10 km	Strong PD for communities	Size
Between villages and cities	NA	Cities, Communities	10 km	Strong PD for communities	NA
Between village ethnicities	NA	Communities	NA	NA	NA
Between city ethnicities	NA	Communities	10 km	NA	NA

The network generation parameters were selected to implement the three power distance levels in SHOUT, low, medium, and high. Table 2 shows the parameters within villages, between villages, and within cities. The parameter *a* shows the probability for connecting to one, two, or three previous nodes. A low and medium power distance have a higher probability to connect to three previous nodes between villages and within cities since there typically are more options to join clusters of closely connected nodes compared to within a village. The effect of preferential attachment is highest within villages and lowest on the country side to account for the difficulty of influencing power over large distances. The distance *rc* is larger within the cities to account for a better communication and transportation infrastructure within cities. Figure 5 shows the degree distribution for a village with 36 communities that was averaged over 20 networks. The three curves for the power distance shows the desired degree distributions where a high power distance gives only a few nodes that are well connected and many nodes that only have contact with a few neighbours. A low power distance, on the other hand, gives a more uniform degree distribution. Similarly, figure 6 shows the degree distribution between 339 villages that was averaged over 20 networks. The three curves for the power distance shows the desired degree distributions where a high power distance gives only a few nodes that are well connected and many nodes that only have contact with a few neighbours. A low power distance, on the other hand, gives a more uniform degree distribution. The distribution for a low power distance is not quite as uniform as in figure 5, since the spatial relationships between villages enhance the preferential attachment.

Table 2: Parameters for social network at three levels of Power Distance. *a* is the probability for only connecting to one previous node, *b* selects the connection distribution, and *c* is the maximum number of connections to neighbours from a previous node.

Power Distance	Within villages					Between villages						Within cities					
	a			b	c	a			b	c	rc	a			b	c	rc
	1	2	3			1	2	3				1	2	3			
Low	0,75	0,25	0	0	3	0,75	0,15	0,1	0	3	5	0,75	0,15	0,1	0	3	10
Medium	0,9	0,1	0	1	2	0,9	0,05	0,05	0,5	2	5	0,9	0,05	0,05	0,7	2	10
High	0,95	0,05	0	2	1	0,95	0,05	0	1	1	5	0,95	0,05	0	1,7	1	10

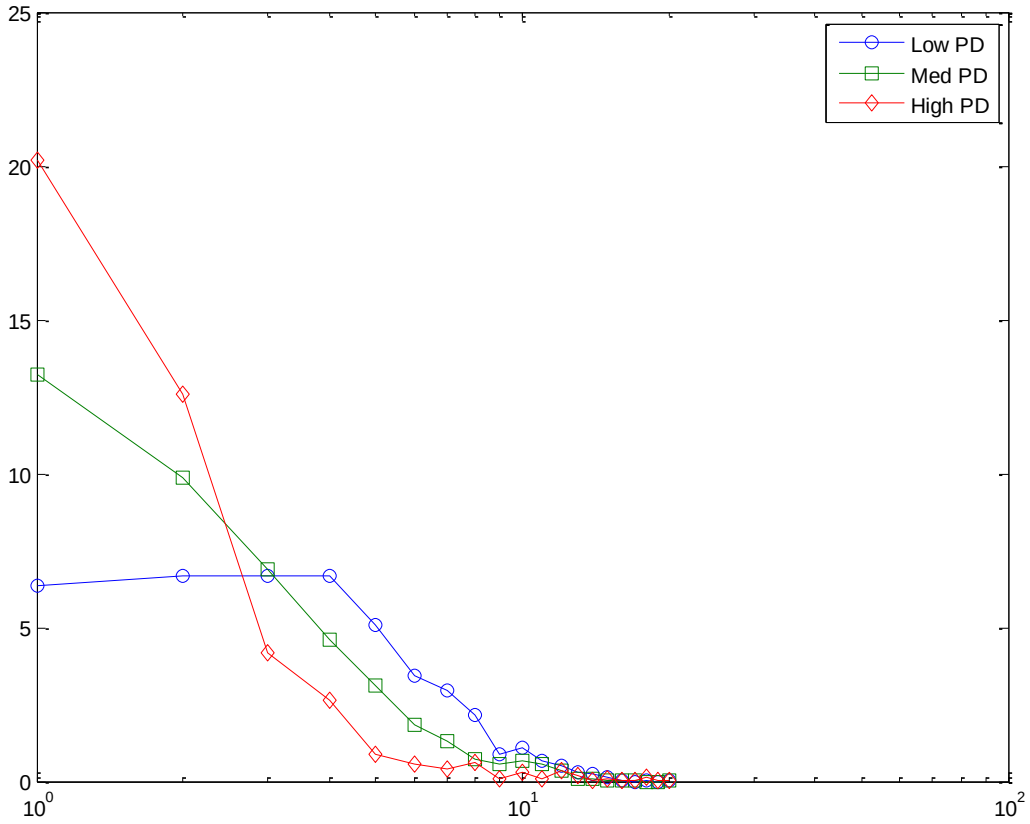

Figure 5: Degree distribution for three levels of power distance in a village with 36 communities that was averaged of 20 networks.

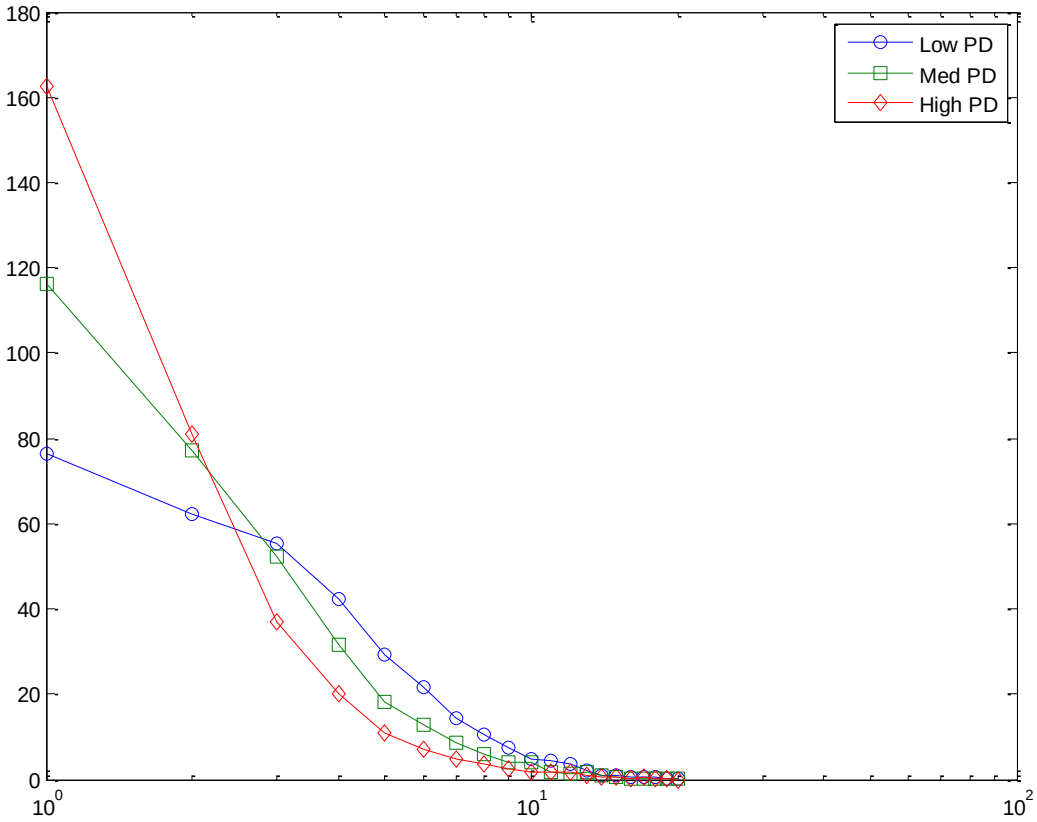

Figure 6: Degree distribution for three levels of power distance between 339 villages that was averaged of 20 networks.

Finally, the areas Gävle City, Sandviken City, and RV80 were treated as one city when generating the social network since the whole area is densely populated. However, they were treated separately for connections between villages and cities.

4.2 Computation of Contact and Transition Rates

Many of the effects between socio-cultural dimensions and message dissemination in section 2 are analysed using correlation and regression coefficients. A reasonable assumption is therefore that the contact rate within and between communities can be represented as weighted linear equations. Equation 3 describes such a linear equation.

$$r = \sum_i c_i w_i \qquad \text{(Eq. 3)}$$

The contact rate between two communities of the same ethnicity depends on the ethnicity's cross-cultural psychology, which in SHOUT is represented by how the ethnicity rate on the Hofstede dimensions. The contact rate between communities of the same ethnicity is estimated using a weighted linear equation that combines the Hofstede ratings in section 3 with the Hofstede weights in section 2. The ordinal terms low, medium, and high for the Hofstede dimensions in section 3 are represented as a scale from 1 to 3 with the integers 1, 2, and 3, respectively. The ordinal terms medium and high for the Hofstede weights in section 2 are represented as a scale from -1 to 1 with -0.5 or 0.5 for medium and -1 or 1 for high, respectively. A negative weight represents a negative influence on the contact rate. A within culture coefficient can then be computed by multiplying each rating with the corresponding weight and summing the results. Finally,

assuming that the weights and the resulting scale is constant, the within culture coefficient is rescaled from 0 to 1 as an estimate of the contact rate.

Similar to the contact rate between communities of the same ethnicity, the contact rate between two communities of different ethnicities is estimated using a weighted linear equation that combines the socio-cultural ratings in section 3 with the socio-cultural weights in section 2. However, the contact rate between two communities of different ethnicities depends on the ethnicities' cross-cultural communication, which in SHOUT is represented by the Hofstede dimensions, as well as typical socio-cultural dimensions that are relevant for cross-cultural communication. The Hofstede ratings are computed to reflect the partially asymmetric cross-cultural communication effects described in section 2. All ratings are represented on the same scale from 1 to 3 and the weights from -1 to 1. The between culture coefficient is similarly computed by multiplying ratings and weights and summing the results. Assuming that the weights and the resulting scale is constant, the between culture coefficient is then rescaled from 0 to 1 as an estimate of the contact rate. Table 3 shows the resulting representation of the cross-cultural psychology and table 4 the cross-cultural communication.

Table 3: Factors for communication between communities of the same ethnicity.

Cultural Dimensions	Delta Christian	Echo Christian	Weights
Individualism	2	1	-1
Power Distance	3	1	-0,5
Masculinity	3	1	-0,5
Uncertainty Avoidance	2	2	0,5
Long-Term Orientation	1	2	0,5

Table 4: Factors for communication between communities of the different ethnicity.

Cross-Cultural Dimensions	Delta to Echo Christian	Echo to Delta Christian	Weights
Individualism	1	2	1
Power Distance	3	1	-0,5
Masculinity	1	1	0,5
Uncertainty Avoidance	2	2	-1
Long-Term Orientation	1	1	-0,5
Conflict	3	3	-1
Habits	3	3	0,5
Attire	3	3	0,5
Language	3	3	1
Social economic status	1	1	0,5
Religion	2	2	1
Family size	2	2	0,5
Political participation	3	3	1

The resulting base contact rates after scaling is 0,013 for Delta Christians, 0,035 for Echo Christians, 0,01 for Delta to Echo Christians, and 0,013 for Echo to Delta Christians. The contact rates were scaled to correspond to the average communication time during a 24h period, which means that the contact rate was 18 min for Delta Christians, 50 min for Echo Christians, 14 min for Delta to Echo Christians, and 18 min for Echo to Delta Christians. Clearly, there are several factors that place Delta Christians at a disadvantage relative the Echo Christians. The cross-cultural communication between Delta and Echo Christians considers that they only meet at their workplace. These base contact rates are then scaled by up to four

parameters that are likely affect the contact rate: the combined effective size of the two communities that are communicating, their spatial relationship, the stability of their regions, and the number of crossings to another power of authority. The effective size means after considering the effects of age distribution and masculinity. Here a high masculinity is assumed to reduce the susceptible population by 50%. The combined effective size is then scaled by the maximum size of two communities. This effective size factor is then used to scale all contacts rates. Within the cities, on the other hand, there is an additional effect of the distance between the communities. The spatial relationship is therefore considered using the exponential equation in figure 4 which is used to scale the contact rate within cities. Finally, the contact rate between communities in different villages or cities is additionally affected by the power sources and social stability of the respective regions for the communities. Power sources that are known to restrict the freedom of movement, such as the Klykers and Valliens in Xland, will reduce the contact rate when crossing the border between two power sources. Similarly, a decreased social stability in a community's region will decrease the contact rate both within the region and to communities in other regions.

The other parameters in equation 1 are fairly straight forward to compute compared to the weighted sociomatrix. The main factor here is of course the message dissemination rate β_i that has a direct effect on the force of dissemination. The message impact is implemented using three levels of β_i that are the same for all communities, 0,6 for a low impact, 0,8 for a medium impact, and 1 for a high impact message. Similarly, the message impact also affects the message dissemination within communities α_i, the rate ψ_i at which communities recover and stop disseminating a message, and the proportion υ at which enough people have heard the message and it looses its news value. All these factors are the same for all communities and increase with an increased message impact. Additionally, α_i is affected by the social stability where a decreased social stability increases the contact rate within communities. Finally, since the discrete metapopulation model is constrained by the minimum path length in the sociomatrix, β_i, σ_i, and ψ_i, were scaled by 24 to allow simulations on an hour resolution. However, logging of the message dissemination was only performed once a day.

4.3 Examples of Message Dissemination with SHOUT

SHOUT simulates the message dissemination using a standalone application as an interface to three commercial off-the-shelf (COTS) software products, where Microsoft Excel is used to specify the cross-cultural and simulation parameters, Matlab (Mathworks) performs the actual simulation of the message dissemination, and Google Earth is used for visualization of the message dissemination. Figure 7 shows an example of the interface to the standalone application.

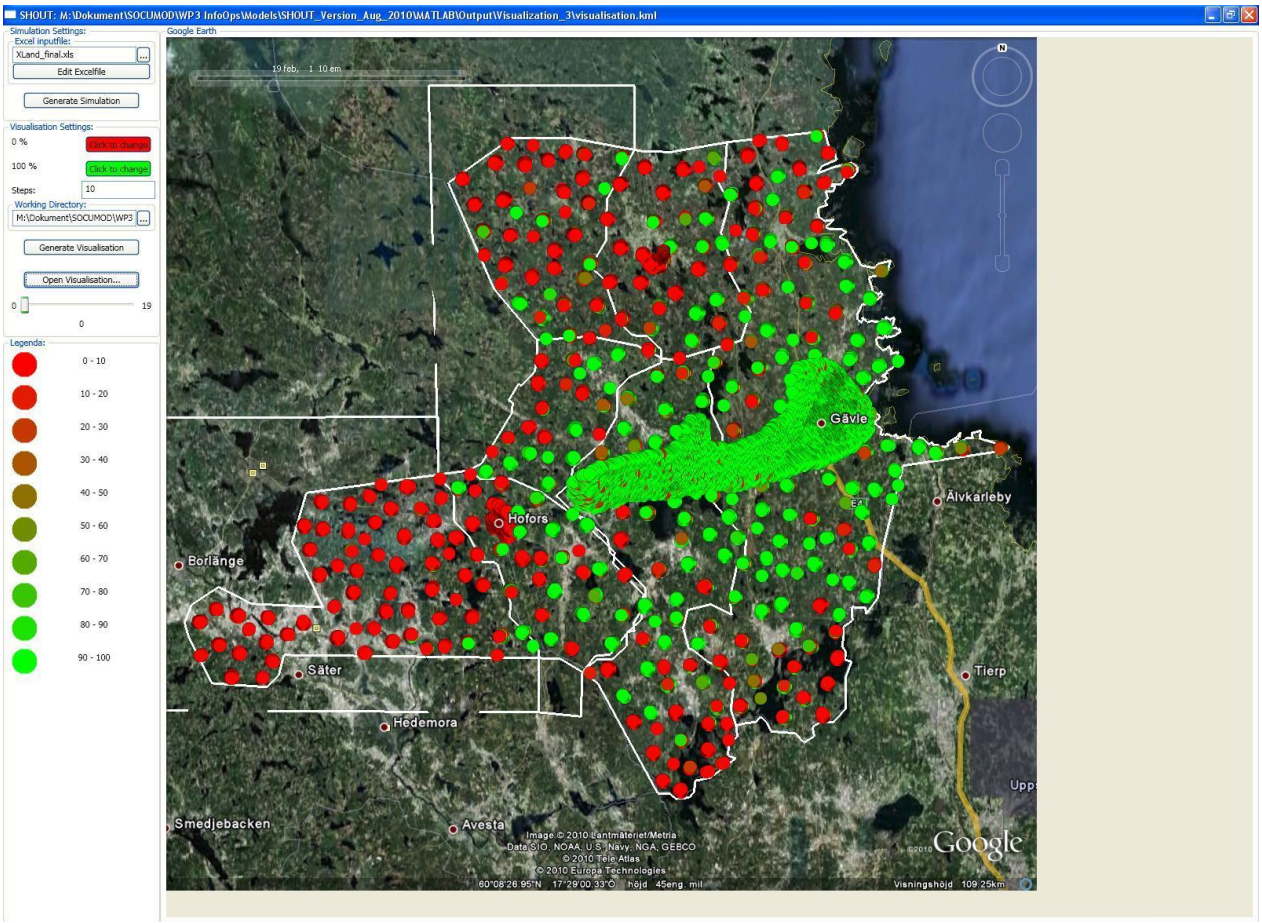

Figure 7: SHOUT interface for specifying simulation parameters, starting the simulation, and generating visualisations. Green circles indicate informed communities and red circles uninformed communities.

An initial assessment of simulated message dissemination using SHOUT was performed by starting the message dissemination in either the most central Delta or Echo Christian Community in Gävle city. For these two staring points the message impact was varied from low to high. Finally, the message dissemination was simulated over whole Xland, or only over the Delta or Echo Christian part of Xland, respectively. This means that the message only impacts one of the ethnic groups but not the other. Table 5 shows the results of the simulations. The table shows the number of days it takes for whole Xland, the first sub-population, or a sub-population to become completely informed of the message. Overall, the results appear to be reasonable with about three months total time for a message with high impact, 4 ½ months for a message with medium impact, and around 7 ½ months for a low impact message. Inspections show that it takes about 1/3 of the time for the initial message dissemination to get significant traction, the main dissemination then occurs with 1/3 of the time, and the final 1/3 is required to completely inform the most remote villages and communities. The effect of the cross-cultural communication is also evident in that the time for first sub-population to become completely informed is shorter than for when only one sub-population is affected. Finally, there is an interesting interaction effect in that Echo Christians are the first to become completely informed for medium and high impact messages, but Delta Christians are the first to become completely informed for low impact messages.

Table 5: Initial results from simulation of message dissemination in Xland using SHOUT.

Impact	Central Delta in Gävle	Central Echo in Gävle

	Whole Xland	Whole first	Only Delta	Whole Xland	Whole first	Only Echo
Low	229	209 Delta	229	212	205 Delta	230
Medium	138	124 Echo	138	135	117 Echo	134
High	95	87 Echo	95	92	82 Echo	91

5.0 CONCLUSIONS

The main purpose of the current version of SHOUT is to enable an assessment of the feasibility for modelling of message dissemination using epidemiological principles. Overall, the results are favourable in that they appear reasonable for message dissemination in a provincial area and there are interesting cross-cultural effects on the message dissemination. SHOUT may therefore enhance PsyOps-officers understanding of how the interaction between socio-cultural factors affects the message dissemination. Since epidemiological modelling in it self is a fairly well developed discipline, it is mainly the selection, representation, and calibration of simulated socio-cultural factors that will affect the simulation of message dissemination. The paper provides one example of how such factors can be selected, integrated, and applied to a representative scenario. Other applications may well have other types of information available about the social networks and contact rates which need to be incorporated in the model. For example, the quam social networks in Afghanistan that forms from the dependencies between actors may be more representative for this area than social networks based on degree distributions (see [3]). Future evaluations with PsyOps-officers will provide more information about the validity SHOUT and the modelling assumptions.

Finally, future studies should address the many shortcomings of the current paper, such as the simplified social network generation, missing contacts to relatives and previous neighbours (e.g. [31]), effects of trust on interpersonal communication (e.g. [32]), no enclaves of Delta Christians as described in the Xland scenario, how the availability of communication technology affects the contact rate, and the lacking comparison of network measures with theoretical developments in network theory. There is also a need for a clearer theoretical understanding that explains how the social network and contact rates are shaped by socio-cultural factors. The current assumption that extensive social networks are representative for low power distance cultures may well be a confounding with other cultural dimensions, such as individualism versus collectivism. Further, gender egalitarianism often means that men and women have more similar social networks. A coherent framework that provides some understanding how the different social networks and contact rates emerge from the socio-cultural factors will be a valuable contribution to cross-cultural psychology, as well as the understanding how socio-cultural factors affect message dissemination.

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